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CALCAREOUS NANNOPLANKTON OF THE GLOBIGERINA MARLS (LELUCHÓW MARLS MEMBER), MAGURA NAPPE, WEST CARPATHIANS

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Abstract: The Magura Nappe, the largest and innermost unit of the outer Carpathians consists of very thick turbidite sequences. In the Leluchów section the upper portion of these sequences includes a regional correlative horizon of pelagic deposits, known as the Globigerina Marls (Sheshor Horizon in the Ukrainian Carpathians). Leluchów section is not typical for the Magura Nappe because it includes green shales, Globigerina Marls and the Menilite Beds. Such sequences are typical for other, more external units of the Polish Carpathians. The Globigerina Marls of Leluchów are represented by a 4 m thick complex of alternating green, olive and red marls or marly shales (Leluchów Marl Member of the Malcov Formation). The Globigerina Marls contain a fairly abundant, diversified and moderately well preserved calcareous nannoflora. The assemblage is dominated by Late Eocene species, although reworked Cretaceous, Paleocene and Early Eocene taxa were also found. The association of *Isthmolithus recurvus*, *Discoaster barbadiensis* and *Discoaster saipanensis* is believed to be indicative for the combined interval of zones NP 19-20. On the basis of the pelagic foraminifers the Eocene-Oligocene boundary has been earlier determined in the upper part of the Globigerina Marls. The Globigerina Marls are covered by a few meters thick complex of black shales with intercalations of hornstones and tuffites (Smereczek Shale Member of the Malcov Formation). The deposition of the Globigerina Marls corresponded to a drop in the global sea-level. This event was associated with the beginning isolation of the Carpathian Basin from the Tethyan domain.

Abstrakt: Płaszczowina magurska jest największą i najbardziej wewnętrzną jednostką Karpat Zewnętrznych zbudowaną z bardzo grubych serii fliszowych. W Leluchowie, w stropowej części tej serii, występuje regionalny poziom korelacyjny związany z pelagicznymi marglami globigerinowymi, nazywany również poziomem szeszorskim. W płaszczowinie magurskiej poziom ten występuje w stropie formacji magurskiej (fm) i jest reprezentowany przez czterometrowy pakiet zielonych, oliwkowych i czerwonych margli i łupków marglistych (ogniwo margli leluchowskich (og) formacji malcowskiej (fm)). Margle globigerinowe zawierają bogatą, zróżnicowaną i na ogół dobrze zachowaną nannoflorę wapienną. Zespół ten zdominowany jest przez późnoeoceńskie gatunki. Znaleziono ponadto redeponowane formy kredowe, paleoceńskie i wczesnoeoceńskie. Zespół z *Istmolithus recurvus*, *Discoaster barbadiensis* i *Discoaster saipanensis* reprezentuje łączną zonę NP 19 i NP 20. Na podstawie badań otwornic pelagicznych w najwyższej części margli globigerinowych w Leluchowie wyznaczona została granica eocen-oligocen. Ponad marglami występuje kilkumetrowy pakiet czarnych łupków typu menilitowego z wkładkami rogowców i tufitów. Sedymentacja margli globigerinowych związana była z obniżeniem poziomu oceanu światowego. Wydarzenie to zapoczątkowało izolację basenu karpackiego od Tetydy.

Key words: Globigerina Marls, pelagic deposits, calcareous nannoplankton, Eocene-Oligocene boundary, Magura Nappe, West Carpathians.

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INTRODUCTION

The Outer Carpathians are built up of a very thick complex of Upper Jurassic–Lower Miocene folded flysch deposits. These turbidite sequences include two regional correlative horizons of pelagic deposits. The lower horizon is one of the Cenomanian radiolarian shales, and the upper – of the Globigerina Marls at the Eocene-Oligocene boundary. The age of the Globigerina Marls in the Polish Outer Carpathians was determined on the basis of foraminifers (Blaicher, 1961, 1970; Olszewska 1983, 1984; Malata in: Oszczypko *et al.*, 1990). The calcareous nannoplankton of the Globigerina Marls was studied in the Dukla Unit (Smagowicz in: Olszewska & Smagowicz, 1977) and in the Sile-

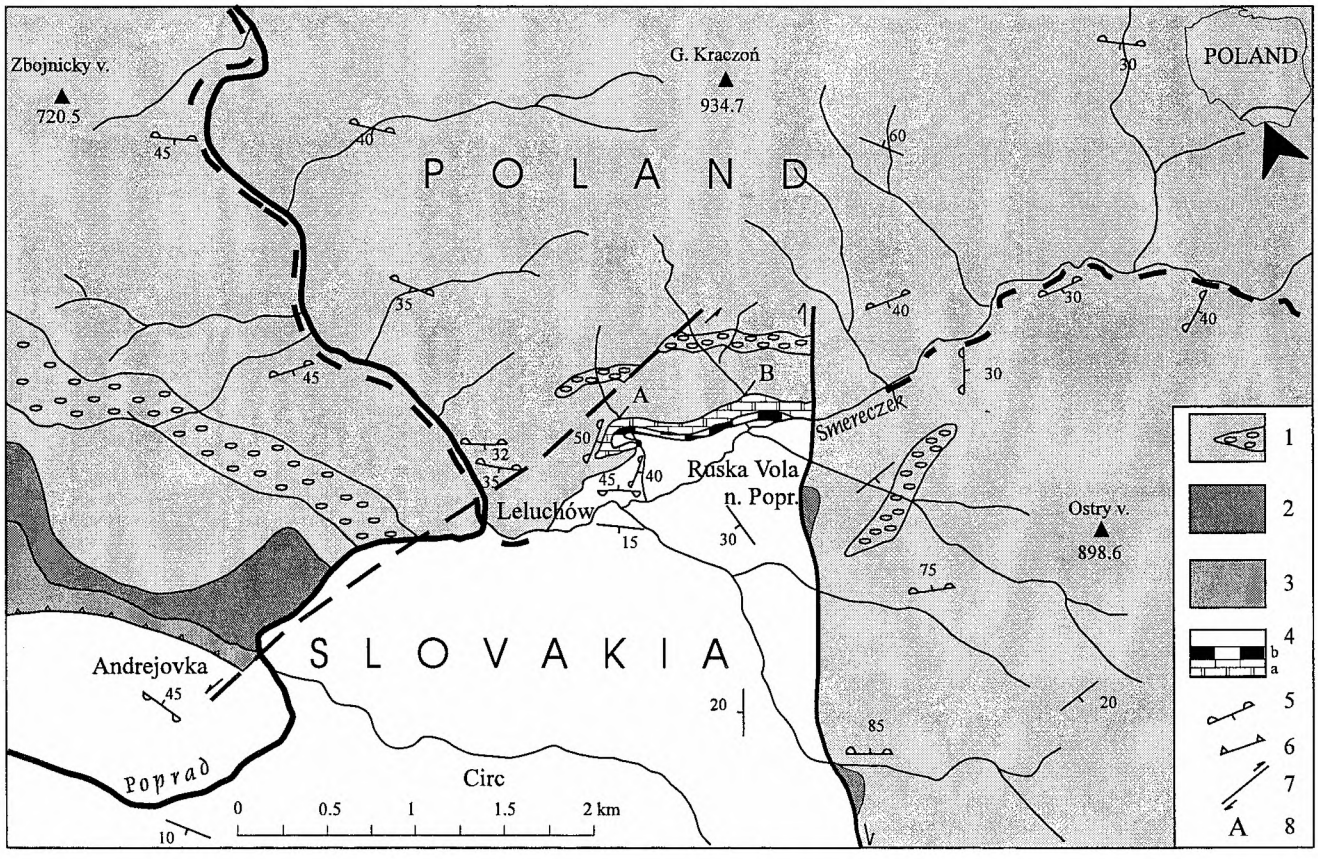


Fig. 1. Geological map of the Leluchów area (after Oszczypko, 1980; Nemčok, 1985; and the present author). Magura F.: *1* – Piwniczna Sandstone Member, *2* – Mniszek Shale Member, *3* – Poprad Sandstone Member, *4* – Malcov Formation : a) Leluchów Marls Member, b) hornstones, *5* – dip and strike of beds, *6* – thrusts, *7* – faults, *8* – studied sections

sian Unit (Aubry in: Van Couvering *et al.*, 1981). The aim of this work (which was prepared as a part of a M. Sc. thesis at the Jagiellonian University) was to recognize and determine the nannoplankton assemblages of Globigerina Marls at Leluchów (Leluchów Marls Member) in the Magura Nappe (Krynica Sub-unit). The Leluchów section through the Oligocene-Eocene boundary is the best exposed in the Polish part of the Magura Nappe.

In the Outer Carpathians, except the Magura Nappe, the Upper Eocene deposits are represented by green shales. These shales pass upward to the Globigerina Marls which make up an important chronostratigraphic horizon (Bieda *et al.*, 1963; Koszarski, ed., 1985) in the Outer Carpathians. In the Magura Nappe, the Globigerina Marls were reported in the Gorlice area (Blaicher & Sikora, 1961) and assigned as submenilite Globigerina Marls of Late Eocene age. At the same time the Globigerina Marls were also recognized in the East Slovakian segment of the Magura Nappe (Książkiewicz & Leško, 1959; Nemčok, 1961).

A detailed lithological and micropaleontological study of the Leluchów section was done by Blaicher and Sikora (1967). This study revealed the following sequence :

– thin-bedded turbidites with intercalation of red and greenish shales (Hieroglyphic Beds, Upper Eocene),

– Globigerina Marls, Oligocene,

– bituminous shales with intercalations of horstones and tuffites (Menilite Beds, Oligocene),

– thin-bedded turbidites (Malcov Beds, Oligocene).

The tuffite from the Leluchów section was correlated with the Gąsiory tuffite horizon (Blaicher & Sikora, 1967). The fission-track age determinations on zircons from the Gąsiory tuffites are: 28.9 ± 1.2 my for the upper layer and 34.6 ± 1.4 my for the lower one (Van Couvering *et al.*, 1981). These data indicate an Early Oligocene (Rupelian) age of the Menilite Beds.

GEOLOGICAL SETTING OF THE LELUCHÓW AREA

The village of Leluchów is located in the Poprad Valley (Fig. 1) in the southernmost part of the Magura Nappe, close to the Pieniny Klippen Belt (PKB). This part of the nappe is represented by a broad (up to 10 km) syncline which is filled with Eocene thick-bedded sandstones (fig. 2) of the Magura Formation (see Birkenmajer & Oszczypko, 1989; Oszczypko *et al.*, 1990; Chrząstowski *et al.*, 1995). The syncline is separateded from the PKB by a strike-slip fault. In the Leluchów area, the Upper Eocene-Oligocene Malcov Formation overlaps the PKB. The Upper Eocene-Oligocene deposits are exposed in two places (sections A and B in Fig. 3) and were previously described by Birkenmajer and Osz-

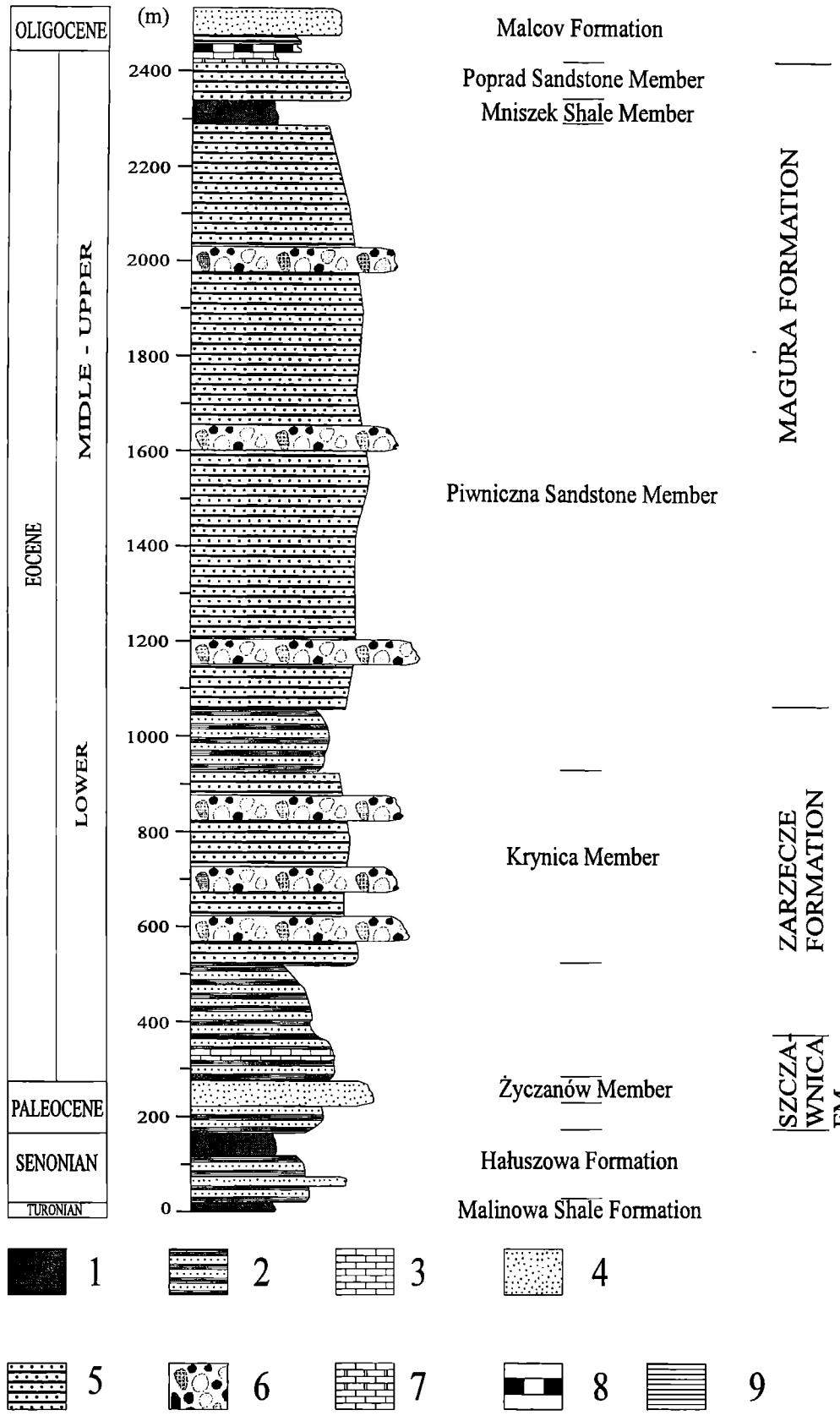
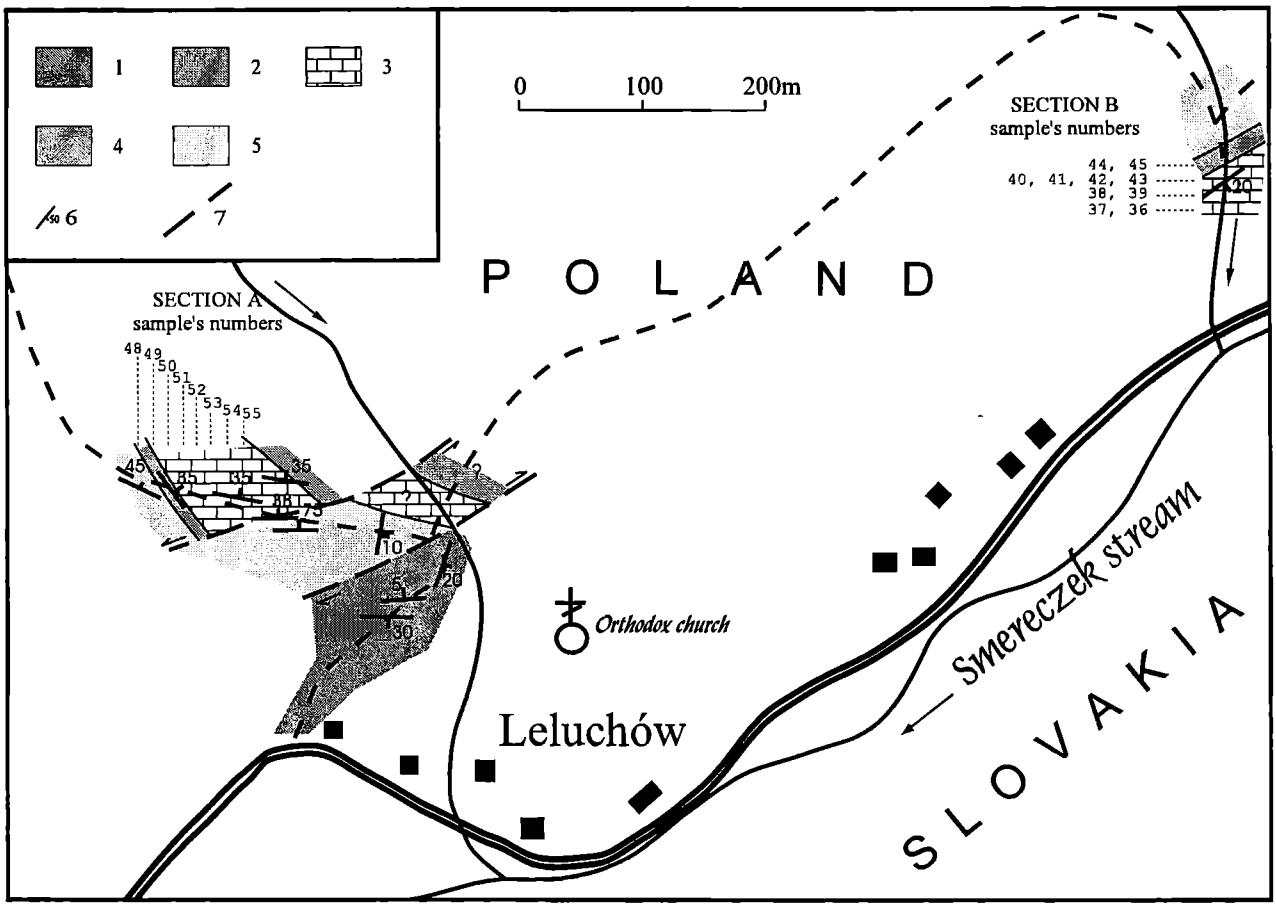


Fig. 2. Lithostratigraphic division of the Magura Nappe in the Muszyna area (after N. Oszczypko, 1995; unpublished). *1* – red shales, *2* – thin-bedded turbidites, *3* – turbidite limestone, *4* – conglomerates, *5* – thick-bedded turbidites, *6* – pebbly mudstone, *7* – Globigerina Marls, *8* – hornstones, *9* – Menilite (bituminous) Shales



Fiig. 3. Location of the Globigrina Marls exposures at Leluchów. *1* – thin-bedded turbidites, *2* – menilite (bitumineous) shales, *3* – Globigerina marls, *4* – green marly shales, *5* – thick-bedded turbidites, *6* – deep and strike of beds, *7* – faults

czypko (1989), Oszczypko *et al.*, (1990). Section A is located along a path, close to the orthodox church and section B is along a small right tributary of the Smereczek stream (Fig. 3).

During the field study of the top part of the Magura Formation (Figs. 2, 4), the author recognized the following lithostratigraphic units, belonging to the Malcov Formation: Globigerina Marls (Leluchów Marls Member), black, bituminous shales with hornstones and tuffites (Smereczek Shale Member) and thin-bedded turbidites of the Malcov Formation. Certain investigated sequences were identical with those already described by Birkenmejer and Oszczypko (1989). A comparison with the sequence described by Blaicher and Sikora (1967) revealed important differences: a lack of the Hieroglyphic Beds with an intercalation of red shales at the base of Globigerina Marls, a higher thickness of Globigerina Marls and a significantly lower thickness of Menilite Beds. Assuming that the data of Blaicher and Sikora are correct, the lack of Hieroglyphic Beds can be explained in a way that Blaicher and Sikora's column was synthetic, and the exposures or excavation of the Hieroglyphic Beds were located between sections A and B, somewhere on the slope south of the church (Figs. 1, 3, 4). It means that the Hieroglyphic Beds (Mniszek Shale Member, see Birkenkmajer & Oszczypko, 1989; Oszczypko *et al.*, 1990) could occur just below the Globigerina Marls and the Poprad Sandstone Member is missing in this section. According to Chrząstowski *et al.* (1995) the contact between the Magura and the Malcov formations is tectonic.

LITHOSTRATIGRAPHY

The bases of both Leluchów sections (A and B) consist of thick-bedded sandstones and conglomerates (Figs. 3, 4). The muscovite sandstones are grey-bluish and coarse to fine grained, with interaclations of granule conglomerates. The sandstones display T_{abc} Bouma sequences. The thicknesses of individual beds range from 40 cm to 2,5 m. The infrequent shale-mudstone intercalations are very thin (1-5 cm). Rare 2-5 m thick packets of thin-bedded turbidites are also observed. These deposits belong to the Piwniczna Sandstone Member of the Magura Formation. In both sections (A and B), the contact between the Piwniczna Sandstone Member and the overlying marly shales is not exposed (1-2 m of break in exposure). The marly shales are soft and green with numerous calcite vains. The thicknesses vary from 0.5 m (profile A) to 2.5 m (profile B) and are overlain by a 4 m thick marly unit of the Leluchów Marls Member. The sequence of marls is as follows:

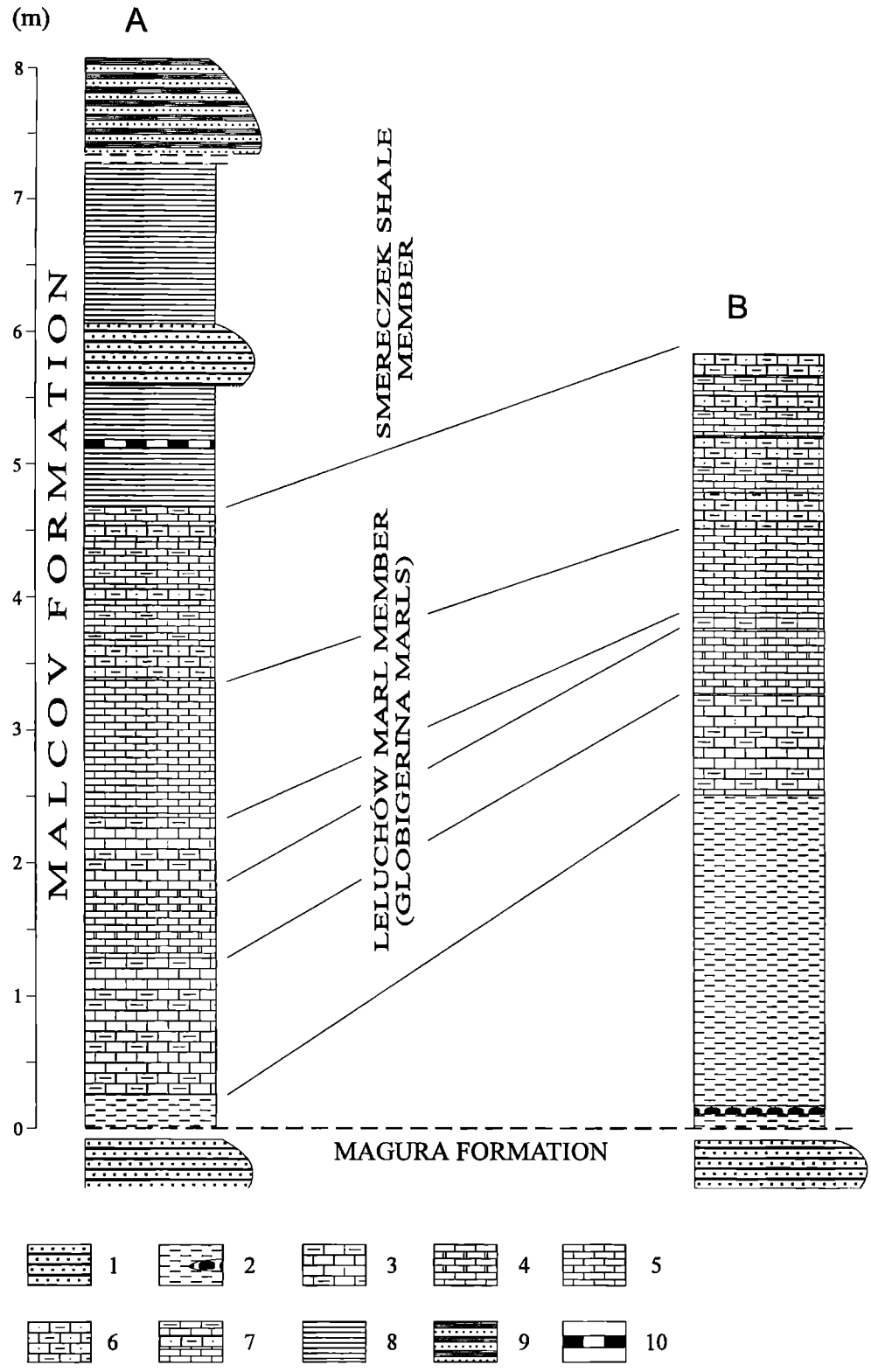


Fig. 4. Sections of the Globigerina Marls at Leluchów. *1* – thick-bedded turbidites, *2* – green marly shales, a – Mn concretions; *3* – red marls, *4* – greyish-green marls, *5* – greenish marls, *6* – olive marls, *7* – grey calcareous shales, *8* – Menilite (bituminous) shales, *9* – thin-bedded turbidites, *10* – hornstones

AGE		BUKRY (1973)			MARTINI (1971)	
		ZONE		SUBZONE		ZONE
OLIGOCENE	E	CP 16	*Helicosphaera reticulata*	CP 16c	NP 22	*Helicosphaera reticulata*
				CP 16b	NP 21	*Ericsonia subdisticha*
				CP 16a		
EOCENE	L	CP 15	*Discoaster barbadiensis*	CP 15b	NP 19-20	*Isthmolithus recurvus*
				CP 15a	NP 18	*Chiasmolithus oamaruensis*
	M	CP 14	*Reticulofenestra umbilica*	CP 14b	NP 17	*Discoaster saipanensis*
				CP 14a	NP 16 & NP 15	*Discoaster tani nodifer*
		CP 13	*Nannotetrina quedrata*	CP 13c		*Nannotetrina fulgens*
				CP 13b		
				CP 13a		
		CP 12	*Discoaster sublodoensis*	CP 12b	NP 14	*Discoaster sublodoensis*
	E			CP 12a		

Fig. 5. Nannoplankton biostratigraphy of the Late Eocene and Early Oligocene (after Martini, 1971; Bukry, 1973; Okada & Bukry, 1980)

– 1 m of red marls,
– 0.5 m of greyish-green marls,
– 0.5 m of red marls,
– 1 m of greenish marls,
– 0.25 m of olive marls,
– 1 m of grey calcareous shales.

Just above the calcareous shales, the Smereczek Shale Member is reported (Birkenmajer & Oszczypko, 1989). This member consists of dark bituminous shales with thin (2-5 cm) beds of hornstones (Fig. 4). A very thin tuffite bed ("Gąsiory" ? horizon) was also found in the lower part of the Smereczek Shale Member. The uppermost part of the Leluchów section are thin-bedded turbidites of the Malcov Formation exposed in the road-cut beneath the church. These flat-laying, south dipping strata consist of Krosno-like, dark-grey marly shales with intercalations of thin bedded (10-12 cm), cross-laminated, fine to very fine grained, bluish calcareous sandstones.

NANNOPLANKTON BIOSTRATIGRAPHY OF THE LATE EOCENE

The most popular Paleogene coccolith zonations are the standard zonation of Martini (1971) and the zonation by Bukry (1973), Okada and Bukry (1980). The comparison of these two zonations (Middle Eocene through Lower Oligocene) is presented in Fig. 5.

The first occurrence (FO) of *Isthmolithus recurvus* Deflandre has traditionally been used as the base of the uppermost Eocene. However, this taxon is not a reliable marker in the lower latitudes. The FO of *Sphenolithus pseudoradians* Bramlette et Wilcoxon has been also used as a zonal marker for the Upper Eocene. The FO of these species seems to be controversial as the taxon has also been reported in the Middle Eocene. The Upper Eocene is therefore no longer considered as two separate zones NP 19 and NP 20, but as a combined zone NP 19-20 (Aubry 1983), which is equivalent to subzone CP 15b (Okada & Bukry, 1980). For a long time the last occurrence (LO) of *Discoaster barbadiensis* Tan Sin Hok or *Discoaster saipanensis* Bramlette et Riedel has been used as the coccolith event marking the Eocene-Oligocene boundary which coincides with the base of NP 21 (Martini & Ritzkowski, 1968). However, Cavelier (1979) showed that the extinctions of *Discoaster saipanensis* and *Discoaster barbadiensis* had been diachronous and had occurred earlier in high latitudes than in the low ones. It proved that the lower limit of zone NP 21 ranges in age from Late Eocene to Early Oligocene.

NANNOPLANKTON OF THE GLOBIGERINA MARLS IN LELUCHÓW SECTION

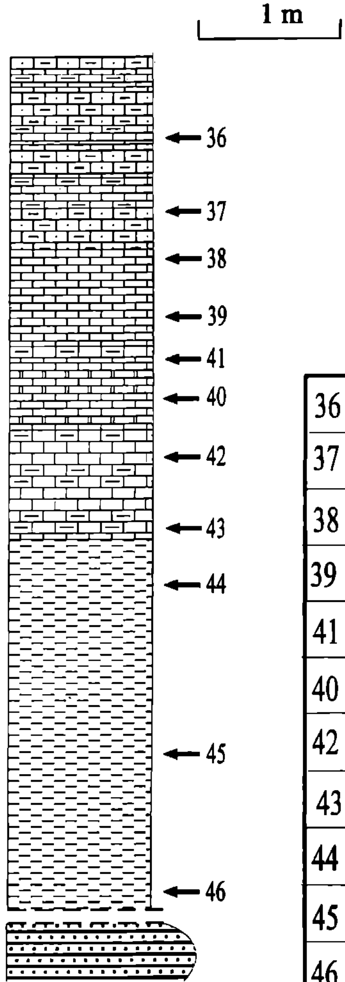
Studied material and methods

The studied samples were collected by M. Sc. E. Malata and Prof. N. Oszczypko during their field work in 1982. All samples were prepared by using the standard smear slide technique for light microscope (LM) observations. The investigation was carried out under LM at magnifications of 1024x and 1600x using phase contrast and crossed nicols. Several specimens photographed in LM and scanning electron microscope (SEM) are illustrated in Figures 8-10.

The Globigerina Marls exposed at Leluchów contain a

	55	54	53	52	51	50	49	48
Braarudosphaera bigelowii	R							
Chiasmolithus sp.				F				
Chiasmolithus medius			R					
Chiasmolithus oamaruensis	R							
Coccolithus pelagicus	A	A	A R	A	A F	C	A F	A F
Coronocyclus nitescens					R		F	F
Coronocyclus cf. C. nitescens					R	F	F	F
Cribrocentrum coenurum	R							
Cyclagosphaera alta					R			
Cyclicargolithus aff. C. abisectus	C	C	C	C	R	C		A
Cyclicargolithus floridanus	A	A	C C	A	A C	A C	C A	C C
Dictyococcites sp.	C		C C	A	C	C	C	C
Dictyococcites bisectus.	A	A	C A	A	C R	C	A	C
Dictyococcites callidus					A			
Dictyococcites hesslandii	A	A	A	A	A	A	C	A
Discoaster sp.	F			A F		F	C F	A F
Discoaster barbadiensis					F		F	F
Discoaster deflandrei	F	F		F	F		F	F
Discoaster saipanensis			F	F	F	F	F	R
Discoaster tani	F			F			F	
Discoaster tani nodifer	F							
Ericsonia sp.	F		F	F	F	F	F	F
Ericsonia cava	F					F	F	F
Ericsonia formosa	F		F	F	F	F	C	F
Fasciculithus tympaniformis				F	F			
Helicosphaera compacta	R							
Helicosphaera dinsenii/ haqzenii					R			
Helicosphaera euphratis					R			R
Isthmolithus recurvus	C	C	F C	C	F	C	A	F
Lanternithus minutus	F	F	C	R				
Prinsus cf. P. bisulcus				R				
Pontosphaera sp.								R
Reticulofenestra clatrata/ lockeri	F		F C	C R	C	C		
Reticulofenestra dictyoda	C	C	C	C R	C	C F	C	C R
Reticulofenestra hillae		F		R		F		R
Reticulofenestra reticulata	F	F	F			F	F	F
Reticulofenestra cf. R. reticulata	F	F	F	F C	F	F	F	F
Reticulofenestra umbilica	C	F		C	F	C	C	F
Rhabdosphaeraceae indet.	C	C	C R	C	C	C	C F	C
Sphenolithus morliformis	F	C	C	C	F	C	F	
Sphenolithus spinigeri	F		R		F	C		
Thoracosphaera operculata	F			F	F	C	F	R
Towelius gammation					F			
Tranversopontis pulcheroides	R							
Zygrhablithus bijugatus	F	F	C	F	C	F	F	R

Fig. 6. Distribution of calcareous nannofosils in section A. V – very abundant, A – abundant, C – common, F – few, R – rare



	Braarudosphaera bigelowii	Chiasmolithus sp.	Chiasmolithus medius	Chiasmolithus oamaruensis	Chiasmolithus cf. C. oamaruensis	Coccolithus pelagicus	Coronocyolus nitescens	Coronocyclus cf. C. nitescens	Cribrocentrum coenurum	Cyclicargolithus aff. C. abisectus	Cyclicargolithus floridanus	Dictyococcites sp.	Dictyococcites bisectus.	Dictyococcites callidus	Dictyococcites hesslandii	Discoaster sp.	Discoaster barbadiensis	Discoaster deflandrei	Discoaster tani nodifer	Discoaster saipanensis	Discoaster cf. D. saipanensis	Discoaster tani	Ericsonia sp.	Ericsonia cava	Ericsonia formosa	Fasciculithus tympaniformis	Helicosphaera compacta	Helicosphaera dinsenii/ heezenii	Helicosphaera euphratis	Isthmolithus recurvus	Lanternithus minutus	Pontosphaera sp.	Reticulofenestra clatrata/ lockeri	Reticulofenestra dictyoda	Reticulofenestra hillae	Reticulofenestra reticulata	Reticulofenestra cf. R. reticulata	Reticulofenestra umbilica	Rhabdosphaeraceae indet.	Sphenolithus moriformis	Sphenolithus spiniger	Thoracosphaera operculata	Toweius gammation	Tranversopontis pulcheroides	Zygrhablithus bijugatus
36	R	C	F	F		A	C	R	R	C	A	C	A	R	C	F	R	C	F	R	F		F	F	C		R			C			C	C	C	C	C	A	C	F	F	C		F	F
37		F		R		A	F			C	A	C	A		A	F	F	F		R	R	R	F	F	F								C	C	F	R	C	C	A	C	C	C			F
38		A				A	R			C	A	C	A		A	C							R		C	F					F		F	C			F	F	A	C	F	F			F
39						C				C	A	A	C		A	F		F					R		F						F		C	F			F		A	R	F	C			F
41						A	R			C	A	C	A		A	F		R		F		F	C		F	F		R	R				C	F		F	C	F	C	C	F	C	F		F
40						A				C	A	A	C		A	C	F	C	F	R	F	F	F		C								C	C	R	R	F	F	A	C	F	C			C
42						A					C	A	A		C					F			F		R						F			F	R	R			A	C	F	F			C
43						A					A	C	A		A	C	R	C		F		F	F		C								F	C	C	F	F	C	C	F	F				F
44						A					A	A	A		A	C	R	C			F	F	F		C								C	C	R	F	F	F	C	C	F	F			F
45						A					C	C	A		A	C	F	C			F	F	R		C								F	C	F	F		F	C	F	F	F			F
46						A					A	C	A		A	F	F	C			F	F	C		C				R					C	C	F	F	C	C	C		C			R

Fig. 7. Distribution of calcareous nannofosils in section B. (for explanation see Fig.6)

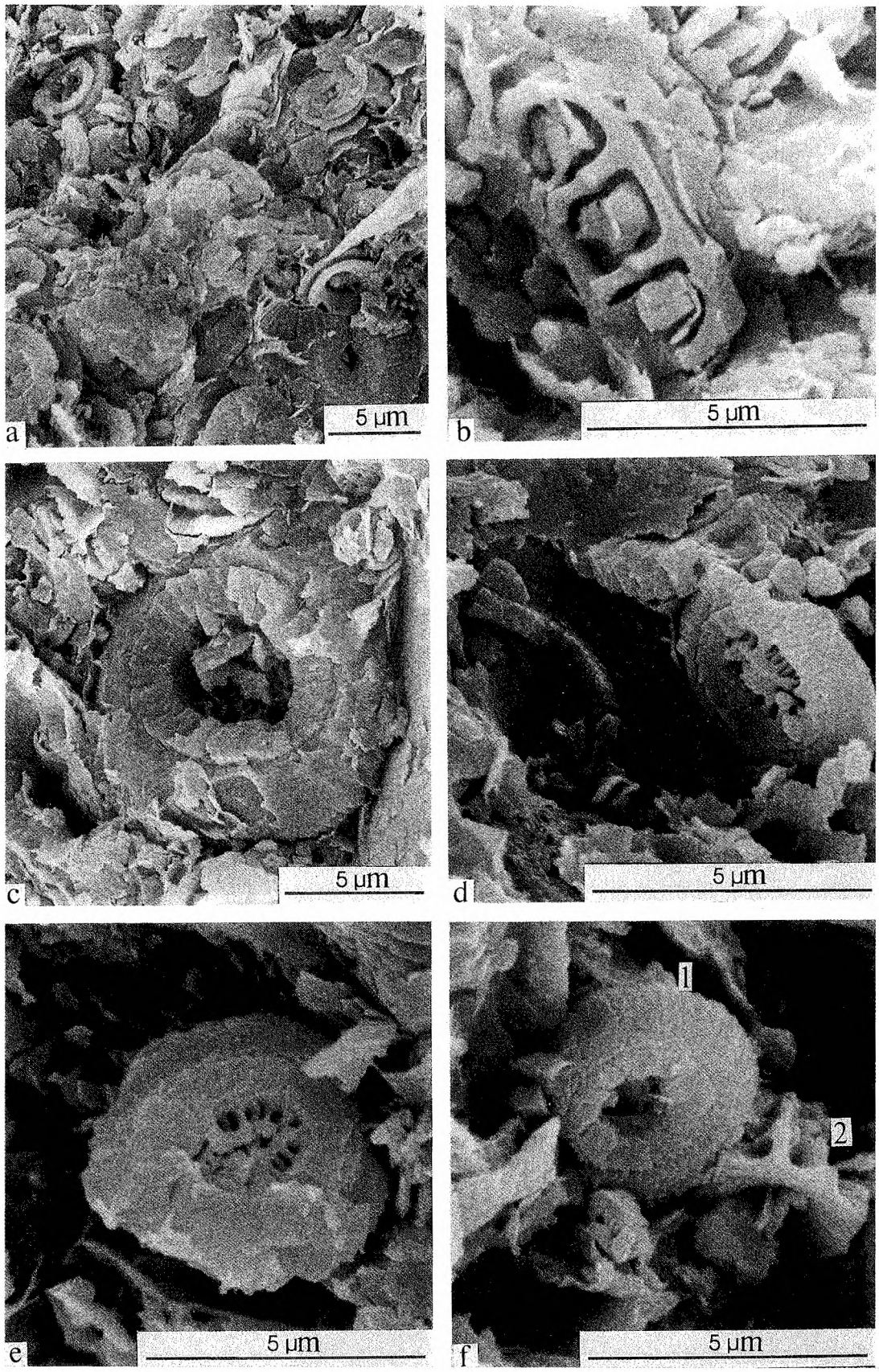


Fig. 8. SEM micrographs. **(a)** rock surface Leluchów, section A, sample 55; **(b)** *Isthmolithus recurvus*, Leluchów, section A, sample 55; **(c)** *Reticulofenestra hillae*, Leluchów, section A, sample 55; **(d)** *Reticulofenestra umbilica*, Leluchów, section A, sample 55; **(e)** *Reticulofenestra reticulata*, Leluchów, section A, sample 55; **(f1)** *Cyclicargolithus* aff. *C. abisectus*, Leluchów, section A, sample 55; **(f2)** *Sphenolithus moriformis*, Leluchów, section A, sample 55

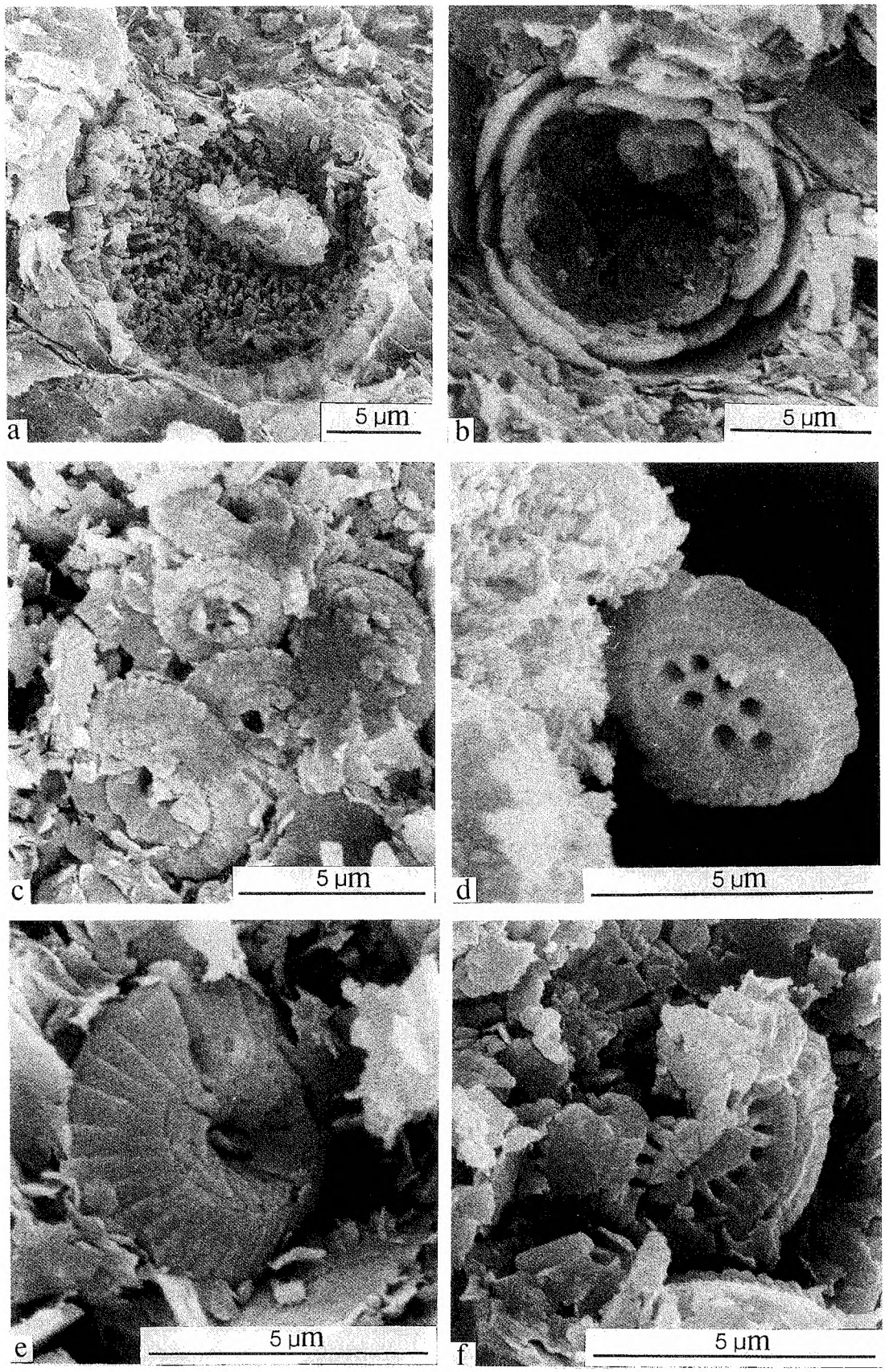


Fig. 9. SEM micrographs. **(a)** *Thoracosphaera operculata*, Leluchów, section A, sample 55; **(b)** Coccosphere of *Prinsiaceae*, Leluchów, section A, sample 55; **(c)** Coccosphere of *Dictyococcites bisectus*, Leluchów, section A, sample 55; **(d)** *Pontosphaera enormis*, Leluchów, section A, sample 55; **(e)** *Coccolithus pelagicus*, Leluchów, section A, sample 55; **(f)** *Dictyococcites callidus*, Leluchów, section A, sample 55

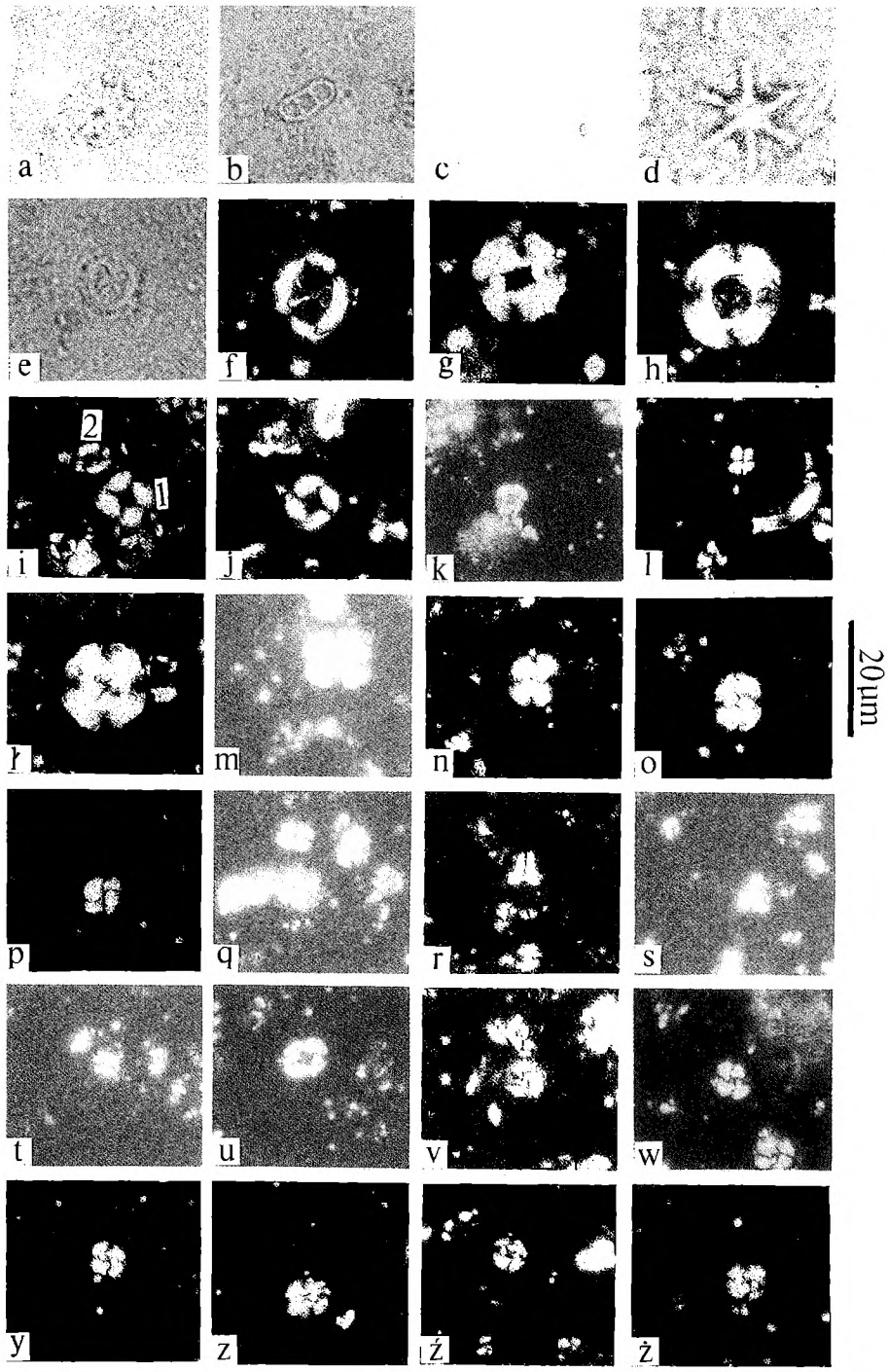


Fig. 10. LM microphotogaphs. **(a)** *Discoaster barbadiensis*, Leluchów, section A, sample 51; **(b)** *Isthmolithus recurvus*, Leluchów, section A, sample 53; **(c)** *Isthmolithus recurvus*, Leluchów, section B, sample 36; **(d)** *Discoaster tani*, Leluchów, section B, sample 36; **(e)** *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; **(f)** *Chiasmolithus oamaruensis*, Leluchów, section A, sample 55; **(g)** *Reticulofenestra hillae*, Leluchów, section B, sample 36; **(h)** *Reticulofenestra umbilica*, Leluchów, section B, sample 36; **(i1)** *Ericsonia formosa*, Leluchów, section B, sample 36; **(i2)** *Reticulofenestra clatrata/lockerii*, Leluchów, section B, sample 36; **(j)** *Ericsonia formosa*, Leluchów, section B, sample 36; **(k)** *Reticulofenestra* cf. *R. reticulata*, Leluchów, section A, sample 36; **(l)** *Sphenolithus moriformis*, Leluchów, section B, sample 43; **(l)** *Dictyococcites bisectus*, Leluchów, section A, sample 53; **(m)** *Dictyococcites bisectus*, Leluchów, section B, sample 36; **(n)** *Dictyococcites* sp., Leluchów, section A, sample 53; **(o)** *Dictyococcites* sp., Leluchów, section A, sample 53; **(p)** *Dictyococcites* sp., Leluchów, section A, sample 55; **(q)** *Lanternithus minutus*, Leluchów, section A, sample 53; **(r)** *Dictyococcites* sp., Leluchów, section B, sample 36; **(s)** *Zygrhablithus bijugatus*, Leluchów, section A, sample 53; **(t)** *Zygrhablithus bijugatus*, Leluchów, section A, sample 53; **(u)** *Toweius crassus*, Leluchów, section A, sample 51; **(v)** *Toweius gammation*, Leluchów, section A, sample 51; **(w)** *Dictyococcites hesslandii*, Leluchów, section B, sample 43; **(y)** *Cyclicargolithus* aff. *C. abisectus*, Leluchów, section A, sample 55; **(z)** *Cyclicargolithus* aff. *C. abisectus*, Leluchów, section A, sample 53; **(ź)** *Cyclicargolithus* aff. *C. abisectus*, Leluchów, section A, sample 53; **(ż)** *Cyclicargolithus* aff. *C. abisectus*, Leluchów, section B, sample 36

fairly abundant but moderately diversified (more than fifty species were recognized) calcareous nannoflora. Reworked Upper Cretaceous, Paleocene and Lower to Middle Eocene taxons were also found.

For the purpose of this work a 5-grade scale describing the frequency of specimens was used:

V - very abundant (more than 10 specimens per field of view)

A - abundant (1 -10 specimens per field of view)

C - common (1 specimen per 2-10 fields of view)

F - few (1 specimen per 11 -50 fields of view)

R - rare (1 specimen per more than 50 fields of view)

The distribution of calcareous nannofosil species is presented in Figs. 6 and 7.

Taxonomic notes

In the studied material, several morphological transitions between *Dictyococcites bisectus* and *Dictyococcites scrippsae* Bukry et Percival were observed. These morphotypes have been described as *Dictyococcites* sp. Viewed through the crossed nicols the entire coccolith is bright and the central plug is well developed, filling the whole central area. *Dictyococcites* sp. is easily distinguished from *Dictyococcites bisectus* by its smaller size, more elliptical outline and sharply bent extinction line. Another characteristic of *Dictyococcites* sp. is that the central area covers ca. 90% of the whole placolith.

Another morthotype, designed in this paper as a *Cyclicargolithus* aff. *C. abisectus*, is a transitional species between *Cyclicargolithus floridanus* (Roth et Hay) and *Cyclicargolithus abisectus* Müller. The extinction lines of *Cyclicargolithus* aff. *C. abisectus*, between the wall and shield, are typically disjunct and the central opening is smaller. The taxon described here as *Cyclicargolithus* aff. *C. abisectus* differs from *Cyclicargolithus abisectus* by its smaller size and oval rather than elliptical outline.

Biostratigraphical conclusion

The nannoplnakton assemblage of the Leluchów Marls is characterized by the occurrence of *Isthmolithus recurvus*, *Discoaster barbadiensis*, *Discoaster saipanensis*. Such an association is believed to be indicative of the combined interval zone NP 19-20 (Martini, 1971).

Therefore, for the purpose of this work, zones NP 19 and NP 20 are also combined and defined as the interval between FO of *Isthmolithus recurvus* an the LO of *Discoaster saipanensis* or *Discoaster barbadiensis* (Aubry, 1983).

Discussion

The examined samples of the Leluchów Marls are assigned to zone NP 19- 20 on the ground of the occurrence of *Discoaster saipanensis*, *Discoaster barbadiensis*, *Reticulofenestra reticulata*, *Ericsonia formosa* and *Isthmolithus recurvus*. The Globigerina Marls at Znamirowice and Krosno sections (Silesian Nappe) were assigned by Aubry (in: Van Couvering *et al.*, 1981) to zone NP 19-20 and NP 21. The assignment to zone NP 21 was based on a continuing range of *Ericsonia formosa*, following the disappearance of *Discoaster saipanensis* and *Discoaster barbadiensis*. However, in the case of the Leluchów Marls, all samples contain the Upper Eocene index species and there is no evidence that these forms are reworked. Additionally most samples contain *Reticulofenestra reticulata* which is believed to become extinct in the latest Eocene, slightly prior to *Discoaster barbadiensis* and *Discoaster saipanensis*.

The Oligocene nannoplankton zones are based on the LO and FO of various species of genus *Sphenolithus*. However, this typical warm-water genus is rare or even absent in higher latitudes. Thus, in those areas, the boundary between NP 23 and NP 24 is defined by the FO of *Cyclicargolithus abisectus* or *Helicosphaera recta* (Martini & Müller, 1986).

The FO of *Cyclicargolithus* aff. *C. abisectus* has been observed in samples 51 and 41, which could change the zone assignment from NP 19-20 to NP 24. However, in this paper *Cyclicargolithus* aff. *C. abisectus* has been described as a transitional taxon between *Cyclicargolithus floridanus* and *Cyclicargolithus abisectus*. It can therefore be assumed that in the Leluchów Marls Member, *Cyclicargolithus* aff. *C. abisectus* occurred in NP 19-20 which is earlier than normal for *C. abisectus*.

The Late Eocene nannoplankton assemblage of Leluchów Marls is moderately diversified. Haq (1971, 1973) and Bukry (1978) provided evidence of a strong relationship between calcareous nannoflora diversity and the temperature of the ocean water throughout the Paleogene. According to those authors the low diversity is associated with a colder temperature and vice versa. Typical cold-water taxa *Isthmolithus recurvus*, *Zygrhablithus bijugatus*, *Lanternithus minutus*, *Chiasmolithus oamaruensis*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus* are dominant forms in most samples. At the same time the amount of warm-water taxa such as *Reticulofenestra umbilica*, *Discoaster saipanensis* and *Discoaster barbadiensis* is distinctly decreasing towards the top of both profiles.

A quantitative study of the autochtonous nannoplankton assemblage indicates the domination of species belonging to the *Prinsiaceae* family. Most species in this family are typically pelagic, preferring the environment of the open sea. The nearly absence of genera *Helicosphaera* and *Sphenolithus* proves an open sea environment (*cf.* Perch-Nielsen, 1985, 1986).

GEOLOGICAL EVENTS AT THE EOCENE-OLIGOCENE BOUNDARY

In 1987 Haq *et al.* have presented a revised set of the Vail sea level curves (Vail *et al.*, 1977), widely known as the Vail-Haq curve. This eustatic sea-level curve has two components

– a long-term eustatic curve reflecting changes in mid-ocean ridge volumes;

– a short-term eustatic curve reflecting relative changes of sea level indicated by coastal onlap.

The Late Eocene long-term eustatic curve, when compared to the Middle Eocene and the Early Oligocene ones,

indicates a distinct sea-level drop. In this interval on a short-term eustatic curve, one can recognize two minima which correspond to NP 17 and NP 21 respectively. During this time of rapid sea level fall, a lowstand system tract was deposited. Zones NP 18 and NP 19-20 correspond to short oscillations of the sea-level, when transgressive system tracts and highstand system tracts were deposited.

Ocean temperature fell in the Late Eocene to around 4-5°C (Shackleton & Kennett, 1975, 1976; Pomerol & Premoli-Silva, 1986) or even to 3°C (Keigwin, 1980). This cooling can be associated with the formation of sea ice around the Antarctic and, as a result of this, the beginning of a deep cold water circulation (Shackleton & Kennett, 1975). The development of a cold-water current caused migration of warm water nannoflora towards the Equator.

One of the consequences of the Pyrenean orogeny in the Alps was modification of the basin floor in Magura Basin after the deposition of the Mniszek Shale Member (Oszczypko, 1992). As a result of this movement and global drop of sea level, the depression was filled with thick-bedded turbidites (Poprad Sandstone Member), whereas the submarine highs and their slopes have been occupied by pelagic sediments (Leluchów Marls Member). During the Rupelian lowstand, sedimentation in the Magura Basin was dominated by black clays (Smereczek Shales Member). At that time the Carpathian basins became partly separated from the Tethys (Nagymarosy, 1990).

CONCLUSIONS

1. In the Leluchów section the Poprad Sandstone Member is probably replaced by green shales and Globigerina Marls (Leluchów Marls Member). This may indicate that after the deposition of the Mniszek Shales Member, the floor of the Magura Basin was modified by tectonic movements. As a result of this movement and global drop of sea level, the depression has been filled with the thick-bedded turbidites (Poprad Sandstone Member), whereas the submarine highs and their slopes have been occupied by pelagic sediments (Leluchów Marls Member). During the Rupelian lowstand, sediments in the Magura Basin were mostly black clays (Smereczek Shales Member).

2. For the first time green shales have been found in the Magura Nappe. The pelagic shales probably belong to the uppermost part of the Mniszek Shale Member.

3. The Leluchów Marls Member differ from typical Globigerina Marls. Besides grey marls, the Leluchów Marls contain red and green intercalations. They are typically pelagic and enriched in calcareous nannoplankton assemblage which in turn is dominated by taxons from the Prinsiaceae family.

4. All samples from the investigated sections contain a fairly abundant calcareous nannoplankton, which is assigned to combined interval zone NP 19-20 of the standard Martini zonation.

5. The nannoplankton assemblage is dominated by cool-water taxons, which confirm the climatic changes of the Late Eocene.

6. In the investigated section, the unquestionable Oligocene age was determined in Menilite Beds on zircons from tuffite horizon "Gąsiory" (see Blaicher & Sikora, 1967; Van Couvering *et al.*, 1981).

7. Taking into account the fact that the Globigerina Marls of units other than Magura are assigned to zone NP 21, one can assume that sedimentation of the Globigerina Marls could have been finished earlier in the Magura Basin.

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Streszczenie

NANNOPLANKTON WAPIENNY MARGLI GLOBIGERINOWYCH (OGNIWO MARGLI Z LELUCHOWA), PŁASZCZOWINA MAGURSKA, KARPATY ZACHODNIE

Marta Oszczypko

Miejscowść Leluchów położona jest w południowej części płaszczowiny magurskiej (strefa krynicka) w bezpośrednim sąsiedztwie pienińskiego pasa skałkowego (Fig. 1). W odległości około 3 km na SW od Leluchowa szerokość pienińskiego pasa skałkowego gwałtownie zwęża się do kilkuset metrów a miejscami do zera. W następstwie tego flisz podhalański bezpośrednio kontaktuje z eoceńskimi i oligoceńskimi utworami strefy krynickiej płaszczowiny magurskiej (por. Żytko *et al.*, 1989).

Najniższą część profilu w Leluchowie stanowią gruboławicowe muskowitowe piaskowce (Fig. 2) należące do ogniwa piaskowców z Piwnicznej (og) formacji magurskiej (fm). W profilu tym brak jest ogniwa piaskowców popradzkich (og), które prawdopodobnie zastąpione zostało przez łupki zielone oraz margle globigerinowe. Zarówno w profilu A jak i B (Fig. 3, 4) kontakt piaskowców z wyżej leżącymi łupkami nie jest widoczny. Miąższość łupków zielonych jest nie mniejsza od 2,5 m w profilu B oraz 0,3 m w profilu A. Powyżej zalega czterometrowy kompleks czerwonych, zielonych oraz szarych margli globigerinowych, tworzących ogniwo margli leluchowskich (og) formacji malcowskiej (fm) (por. Birkenmajer & Oszczypko, 1989; Oszczypko *et al.*, 1990). Bezpośrednio ponad marglami (Fig. 2) zalegają brunatne, krzemionkowe łupki menilitowe (ogniwo łupków ze Smereczka (og), por. Birkenmajer & Oszczypko, 1989). Wykształcenie margli w Leluchowie odbiega od typowego rozwoju margli globigerinowych w innych jednostkach tektonicznych Karpat Zewnętrznych. Oprócz margli szarych występują tutaj margle czerwone i pstre. Są to osady pelagiczne o czym świadczy zespół nannoplanktonu wapiennego zdominowanego przez gatunki z rodziny *Prinsiaceae*. Przyjmuje się, że do rodziny tej należą gatunki typowo pelagiczne preferujące warunki otwartego morza. Odsłaniające się w Leluchowie margle globigerinowe zawierają obfitą, lecz słabo gatunkowo zróżnicowaną nannoflorę wapienną. Autorka oznaczyła 51 gatunków, z czego 15 zostalo uznane za taksony redeponowane wieku kredowego, paleoceńskiego oraz wczesnoeoceńskiego. Częstość występowania poszczególnych taksonów w próbkach została przedstawiona na Figurach 6 i 7.

Przebadane próbki zawierają bogaty osobniczo zespół nannoflory z *Discoaster saipanensis*, *Discoaster barbadiensis*, *Reticulofenestra reticulata*, *Ericsonia formosa* oraz *Isthmolithus recurvus*. Współwystępowanie wyżej wymienionych form pozwoliło na zaliczenie całości ogniwa do łącznej zony NP 19-20 i oznaczenie wieku na najpóźniejszy eocen (Fig. 5). Natomiast Aubry (in: Van Couvering *et al.*, 1981) w obrębie margli globigeri-

nowych jednostki śląskiej wyróżnia zony NP 19-20 oraz w najwyższej części – NP 21, tę ostatnią na podstawie braku *Discoaster saipanensis* i *Discoaster barbadiensis*, przy równoczesnej obecności *Ericsonia formosa*. Jednakże w przypadku margli z Leluchowa, we wszystkich próbkach występują taksony indeksowe najwyższego eocenu i brak jest prze-słanek, iż są to formy redeponowane. Na podstawie badań otwornic stwierdzono (Malata in: Oszczypko *et al.*, 1990), że granica eocen-oligocen przebiega w najwyższej części margli globigerinowych. Ponad tymi marglami w łupkach menilitowych występują tufity korelowane z dolnooligoceńskim poziomem Gąsiory (por. Blaicher & Sikora, 1967; Van Couvering *et al.*, 1981). Stwierdzony zespół nannoplaktonu wapiennego charakteryzuje się dużym udziałem form zimnolubnych takich jak *Isthmolithus recurvus*, *Zygrhablithus bijugatus*, *Lanternithus minutus*, *Chiasmolithus oamaruensis*, *Coccolithus pelagicus*, *Cyclicargolithus floridanus*. Obecność tych form w profilu potwierdza obniżenie temperatury wód oceanicznych w najpóźniejszym eocenie - wczesnym oligocenie. Przyczyny obniżenia temperatury wód oceanicznych wiąże się z początkiem formowania się lodu morskiego wokół Antarktyki co z kolei spowodowało powstanie przydennych zimnych prądów oceanicznych.

Po osadzeniu się łupków z Mniszka w basenie magurskim miały miejsce ruchy tektoniczne prowadzące do zróżnicowania morfologii dna oceanicznego. W następstwie tego oraz zapoczątkowanego w najwyższym eocenie globalnego obniżenia poziomu morza, w strefach obniżonych osadzały się piaskowce popradzkie, natomiast na wyniesieniach podmorskich oraz ich skłonie margle globigerinowe. W okresie najniższego poziomu morza, który miał miejsce w rupelu, w basenie magurskim podobnie jak w całym basenie Karpat zewnętrznych osadziły się ciemne łupki bitumiczne warstw menilitowych. Wydarzenie to uważa się za początek izolacji basenów karpackich od otwarego zbiornika Tetydy (Nagymarosy, 1990; Oszczypko, 1992).

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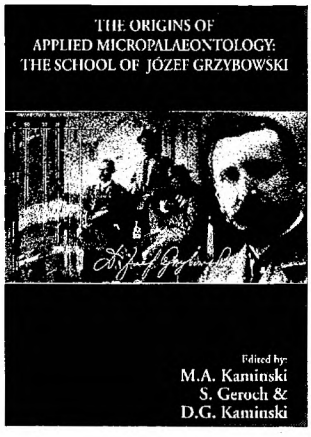

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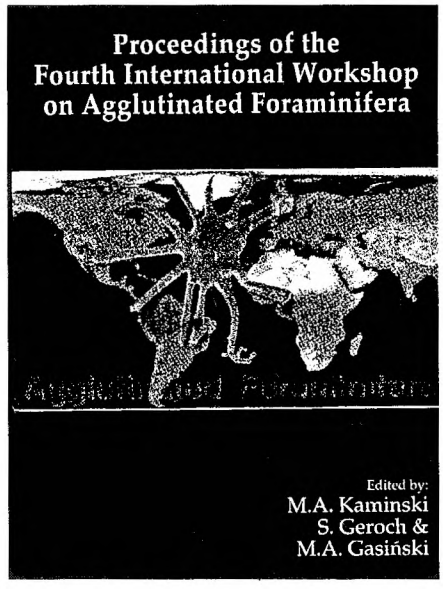

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